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JCS52 U.S. PTO

**UTILITY PATENT
APPLICATION TRANSMITTAL LETTER**

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Box: PATENT APPLICATION
Honorable Commissioner of Patents and Trademarks
Washington, DC. 20231

Sir:

Enclosed for filing is the utility patent application of Francine J. Prokoski for:
**METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION
OF CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES**

Also enclosed are:

- [16] sheets of [] formal [X] informal drawings;
- [] a claim for foreign priority under 35 U.S.C. §§ 119 and/or 365 in [] a separate document
- [X] the declaration;
- [] a certified copy of the priority document;
- [] an Associate Power of Attorney;
- [X] One verified statement claiming small entity status; and
- [] an Assignment document
- [] an Information Disclosure Statement.
- [X] the Declaration of the inventors also is enclosed.


The fee has been calculated as follows:

CLAIMS				
	NUMBER OF CLAIMS	EXTRA	RATE	FEE
Basic Application Fee				\$ 690.00
Total Claims	24	Minus 20 = 4	@ \$20	80.00
Independent Claims	12	Minus 3 = 9	@ \$72	648.00
If multiple dependent claims are presented add \$220.00				0
Total Application Fee				\$ 1418.00
If verified statement claiming small entity status is enclosed, subtract 50% of Total Application Fee				\$ 709.00
Add Assignment Recording Fee of \$40.00 if Assignment document is enclosed				0
TOTAL APPLICATION FEE DUE				\$ 709.00

- [X] A check in the amount of \$709.00 is enclosed.

The Commissioner is hereby requested to notify us of any fees under 37 C.F.R. §§ 1.16, 1.17, and 2.21 that may be required by this paper.

Respectfully submitted,


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Applicant of Patentee: Francine J. Prokoski
Serial or Patent No.: _____
Filed or Issued: _____

For: METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION OF
CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS
(37 C.F.R. §§ 1.9(F) AND 1.27 (B)) - INDEPENDENT INVENTOR

As the below-named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 C.F.R. § 1.9(c) for purposes of paying reduced fees under Section 41(a) and 41(b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION OF CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES

☒ the specification filed herewith
☐ Application Serial No. _____ filed _____
☐ Patent No. _____, issued _____.

I have not assigned, granted, conveyed, or licensed and am under no obligation under contract or law to assign, grant, convey, or license any rights in the invention either to any person who could not be classified as an independent inventor under 37 C.F.R. § 1.9(c) if that person had made the invention, or to any concern that would not qualify as either a small business concern under 37 C.F.R. § 1.9(d) or a nonprofit organization under 37 C.F.R. § 1.9(a).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

☒ no such person, concern, or organization
☐ persons, concerns, or organizations listed below*

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 C.F.R. § 1.27.)

FULL NAME NONE
ADDRESS _____

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earlier of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 C.F.R. § 1.28(b).)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code; and that such willful false statements may jeopardize the validity of the application, and patent issuing thereon, or any patent to which this verified statement is directed.

Name Francine J. Prokoski

Signature

Francine J. Prokoski

Date

8 June 1999

660140-2-000000

**APPLICATION FOR
UNITED STATES LETTERS PATENT**

By

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For

**METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION
OF CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES**

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defects, or hand finishing done in high quality weapons. Breech face marks can be compared just as can firing pin marks, either by firing a test round or by examining the weapon when the weapon is available, or by comparing corresponding marks on two bullets or casings which are suspected of coming from the same weapon. If the same weapon is used to fire the same type ammunition at the same type target from the same distance, comparable patterns will be produced on the bullet and casing. If the ammunition is changed, the patterns will be somewhat different.

Tool marks can be also transferred to the casing by the extractor and ejector of semiautomatics and automatics. Such marks include indentations and striations. The ejector is likely to gouge the casing. The extractor pulls the casing from the breech, imposing perhaps additional striations and indents before it hits the ejector.

Class characteristic marks vary with calibre, load, material used for the bullet or shot, bullet weight, its impact behavior, material used for the casing, and identification stamped into the bullet and casing. Intentional marks on ammunition include information stamped on the face of the bullet casing during molding of the shells. Some casings and bullets also have an indented ring or rings around the circumference called a canellure. These are smeared with grease or wax as sealer, making the bullet water-resistant and providing some lubrication as it is forced through the barrel. The canellures on the casing are imprinted within a quarter inch from the top after the bullet is inserted. This crimp acts to seal the round and hold the bullet in the casing. Canellures may contain imprint information unique to the manufacturer and perhaps to a particular crimping tool.

Ammunition for handguns, rifles and shotguns all contain an outer casing or shell, a primer device to ignite, a fast burning material which is a form of nitrocellulose, and a projectile to fly out the barrel. Ammunition that travels through a particular gun receives scratches from the barrel of the gun, indentation from the firing pin, and perhaps other marks from the breech face and ejector, in addition to fingerprints. The hand of the person firing the weapon receives a spray of gun residue which may be characteristic of a particular type of weapon and ammunition. The target receives some degree of blowback from the weapon and the target itself, plus perhaps fragments of any materials through which the bullet passed.

Markings on ballistic items which are of interest to forensics include:

- Fingerprints on the weapon, projectile, or casing.
- Other debris and material on the weapon, projectile, or casing.

- 1 • Characteristics on the projectile or casing associated with the particular brand and type of ammunition
2 used.
- 3 • Characteristics on the projectile or casing associated with the particular weapon used. These are
4 called tool marks.

5 During manufacture, grooves are cut into the hard steel of pistol and rifle barrels, spiraling from the
6 chamber to the muzzle. They cause the bullet to spin, which results in the bullet having a cleaner trajectory
7 and the weapon having more accurate targeting. The raised areas between grooves are called lands.
8 Bullets are intended to be fired in a particular calibre weapon. Nitrocellulose burns to produce an expanding
9 gas, which drives the bullet through the barrel. The resulting heat causes the bullet to expand and softens
10 its surface. Lead bullets are particularly prone to softening. The bullet is blown out of the shell casing and
11 forced into the barrel, which is tighter. As a result, the lands are cut into the moving bullet and the surface is
12 squeezed into the grooves. The high points of the barrel cause scratches in the bullet, which are referred to
13 as striation evidence. The material used in the bullet determines the depth of the striations.

14 The number, width and depth of the grooves and the angle and direction (right or left) of their spiral
15 are determined by the manufacturer. Lands and grooves together are called rifling. Rifling marks are
16 transferred to the bullet as it is forced through the barrel. Some marks indicate the class of weapon used,
17 while others indicate the particular gun or barrel used in the case of weapons with interchangeable barrels.

18 Most weapons other than Colt use a right twist. The number of lands or grooves typically is four to
19 seven. The width varies depending on the number and the calibre. The degree of twist is measured by the
20 distance traveled during one complete rotation of the bullet. A typical Colt handgun can be described as a
21 left twist, six lands, 1/12. Most handgun barrels are shorter than 12 inches. Therefore, the energy
22 transferred to spinning the bullet is not as great as in a rifle.

23 When the ammunition used is smaller than that designed to be used in a weapon, the result is loss
24 of energy and penetration. In addition, since the bullet is loose within the barrel, inconsistent striations will
25 occur on various bullets fired through the weapon.

26 Maintenance done on a weapon can alter the characteristics imposed on its ammunition. Use,
27 cleaning, corrosion, and intentional damage to a barrel can all affect the ability to match ammunition used in
28 it over time. Rust or corrosion will alter fine details. Some semiautomatics and automatics have
29 interchangeable barrels. After exiting the barrel, the bullet may receive additional distortions as it passes

1 through various materials. The result may be to destroy the forensic value of the bullet, or may be just to
2 require further analysis.

3 The shell casing receives marking from the firing pin hitting the primer, from the back pressure of
4 the gas expansion slamming the casing against the breech face of the firing pin housing which may have
5 marks or defects which transfer onto the primer and/or casing. These marks may be a result of
6 manufacturing defects, or result from the hand finishing done in high quality weapons. Breech face marks
7 can be compared just as can firing pin marks, either by firing a test round or by examining the weapon when
8 the weapon is available, or by comparing corresponding marks on two bullets or casings which are
9 suspected of coming from the same weapon. If the same weapon is used to fire the same type ammunition
10 at the same type target from the same distance, comparable patterns will be produced on the bullet and
11 casing. If the ammunition is changed, the patterns will be different.

12 Shell casings are ejected immediately from automatic and semis, and so fall close to where the
13 firing occurs. Revolvers retain the casings until intentionally ejected, and so are often carried away from the
14 crime scene. Tool marks can be transferred to the casing by the extractor and ejector of semis and
15 automatics. Such marks include indentations and striations. The ejector is likely to gouge the casing. The
16 extractor pulls the casing from the breech, imposing perhaps additional striations and indents before it hits
17 the ejector.

18 Class characteristic marks vary with calibre, load, material used for the bullet or shot, bullet weight,
19 its impact behavior, material used for the casing, and identification stamped into the bullet and casing.
20 Intentional marks on ammunition include information stamped on the face of the bullet casing during
21 molding of the shells. Some casings and bullets, particularly lead, also have an indented ring or multiple
22 rings around the circumference called a canellure. These are smeared with grease or wax when first
23 inserted into the casing. The material acts as sealer, making the bullet water-resistant and providing some
24 lubrication as it is forced through the barrel. The canellures on the casing are imprinted within a quarter
25 inch from the top after the bullet is inserted. This crimp acts to further seal the round and hold the bullet in
26 the casing. Canellures may contain imprint information unique to the manufacturer and perhaps even to a
27 particular crimping tool.

28 Types of ammunition are distinguished by their size. All handguns are designated by calibre in
29 either inches or millimeters. For example a .22 calibre is 22/100 inch. The length of the shell varies to
30 increase the capacity of gunpowder. A .22 may be short, long or long rifle, plus a magnum load. All

1 magnum loads contain more gunpowder and may propel a heavier bullet. Magnum weapons are always
2 designed to be heavier to contain the increased force. A magnum weapon can chamber a regular load, but
3 a regular weapon cannot chamber a magnum round.

4 Some .22 handguns and rifles can chamber only the short, some can chamber short and long, and
5 others can handle all three. The .22 short and long have the same weight bullet, while the long has more
6 powder. The long rifle has more powder still and a heavier bullet but still is not considered a magnum load.
7 All .22 rounds of these types are rim fire primers, rather than center core primers. Some high-powered
8 rifles can proper .22 calibre bullets with center core primers, but the shell casings are huge relative to this
9 group.

10 The .25 calibre pistol purse gun is designed to be easily concealed. There are .32 calibre revolvers
11 and semiautomatics. The .32 calibre rim fire primers were used in early revolvers, but all modern rounds
12 are center core primers.

13 There are two types of ammunition for .38 calibre (.357) revolvers; the .38 S&W and the .38
14 Special. The .38 Smith and Wesson is a shorter shell with smaller load. It has been superceded by the
15 more powerful .38 Special, designed for law enforcement use. The maximum stopping power for the .38
16 calibre became available when the .357 magnum was marketed. The weapon fires a heavier bullet, with
17 longer casing that contains additional gunpowder. However, when firing a solid lead bullet, the weapon
18 proved a hazard to unintended secondary targets, because the penetrating power was too great.

19 For police use, a combination of stopping power and safety are desired. Several .38 calibre bullets
20 are designed to impact only the first target, transferring all the kinetic energy to it. Hollow point bullets were
21 designed for this purpose. A hollow point is a soft lead bullet encased in a thin steel jacket. The point is
22 actually an opening with thin lead walls. On impact the wall flare out. The final shape of the bullet, in the
23 side view is similar to a mushroom. Hence the term "mushrooming" is applied. Hollow points don't
24 necessarily mushroom every time, and can still harm secondary targets, such as by passing through soft
25 tissue of the target and injuring someone behind.

26 Glasser bullets were developed with a prefragmented round constructed of a thin metal skin packed
27 with very small lead particles suspended in liquid Teflon. The bullet's weight is equal to that of a solid lead
28 bullet, resulting in equivalent kinetic energy. When the Glasser hits any resisting surface, the thin walls
29 flatten out, distributing the tiny lead particles over a wide area. A bullet hitting a human or animal penetrates
30 and opens up, transferring all its energy to the inside of the target, having an elephant gun effect. The

1 Glasser offered improved safety since all energy was expended when the bullet hit something. Errant shots
2 striking pavement would not ricochet. Bullets hitting a house would not penetrate walls. Other
3 manufacturers also offer prefragmented bullets.

4 Shotgun shells are different from handgun and rifle ammunition. Although solid metal casings have
5 been used, they are now mostly replaced by a combination casing with a metal face and base connected to
6 a plastic or waxed cardboard cylinder. Shotgun shells are available in gauges 10, 12, 14, 16, 20, and 410.
7 The cylinder is crimped shut, sealing in the projectiles, shot and other materials with the gunpowder. The
8 face contains manufacturer's information and markings and houses a center core primer. The actual
9 projectiles vary. The shot, which was traditionally lead, is gradually being replaced by steel balls. Lead shot
10 has been cited by environmentalists as causing lead contamination in waterways.

11 12 **CURRENT TECHNOLOGY FOR TOOL MARK IDENTIFICATION**

13 Firearms examiners can study the shell casings collected at one crime scene and determine the
14 number of different weapons involved. They can compare the casing to those from other sources. They
15 can also compare bullets to determine the possibility they came from the same weapon, and they can
16 analyze weapons for characteristics which might match bullets and casing fired from it. Current
17 examinations of firearms, bullets and casings use low-powered stereo binocular microscopes combined
18 with high-energy illumination. The systems incorporate computers to assist in finding likely matches
19 between a new casing or bullet and databases of ones previously collected, selecting potential matching
20 items. Although somewhat automated, current techniques are still labor intensive, acting only to select likely
21 matching items for manual review by a ballistics expert. The FBI and the ATF have each established a
22 network of computerized systems to support the identification of guns, bullets, and casings; allowing
23 member labs to share databases.

24 The Drug Fire program started by the FBI in the 1990's has established a network of computers in
25 more than 40 forensic labs that exchange breech face striation information. Each member agency is
26 responsible for classifying all its cases, and placing the information in computer. Any member agency can
27 then compare evidence from its case to all other cases in the system. A second system, Bulletproof
28 developed for the ATF, records striations on the bullet while the casings are categorized by a system called
29 Brass Catcher. The national scope of these two programs is intended to assist in investigations of drug-
30 related gangs with national networks.

The imagery and therefore the analysis is prone to confusion due to inconsistent and aging lighting strength and direction from day to day and from lab to lab. Since there are no registration indices on the fired bullets or casings themselves, the matcher must try a range of rotations and translations for each potential match. Adopted rules, such as aligning the firing pin blow out to 3:00 (three o'clock) are of some assistance in manual placing of casings into the microscope holder. However, that feature is not always present in casings, and when it is, that procedure still allows for variations in rotational position of 5° or more. Manually aligning striations to the 9:00 – 3:00 horizontal is also prone to individual rotational variations on the order of 5° .

The current DrugFire system does not automatically extract and match features by their degree of significance, although it provides some manually assisted techniques for highlighting regions of interest. The current systems are designed to be a filter against the database, locating likely matching items in the database and presenting pages of 25 images at a time on a large screen monitor for a ballistics examiner to review and interactively compare. His comparison involves manually aligning two images on a split screen and looking for matching lines. Such matches may not be obvious without extensive manipulation of contrast, brightness, rotation, and translation of the two images.

A significant limitation to the automatic determination of matching images in a large database is the problem of distinguishing lands and grooves due to variations in the strength and directionality of the illumination. Striations may also run together, confusing the count. Other illumination-induced artifacts may also be created, particularly in the primer area about the firing pin indentation. Imprecise measurement of firing pin position and lack of detail on the shape of the indent, end points and width of striations, and other specific feature characteristics also result from illumination variations. As a result, visual images do not currently provide the capability for large database partitioning and searches based upon extraction and characterization of features.

1 The need is for a ballistics matching technology which is faster and cheaper than current techniques,
2 which finds more correct matches with less manual intervention by a ballistics examiner, and which can
3 exploit the current databases and enhance the performance of existing ballistics identification systems. The
4 goal is to increase the capacity of the law enforcement community to identify increasing numbers of ballistic
5 items, faster and with greater accuracy, and at minimum cost both in terms of manpower and system
6 expenses.

7 The situation is analogous to that of fingerprint matching. As increasingly large databases are created,
8 techniques are needed to partition those databases and to perform matches based upon feature
9 characteristics, with full image comparison being performed on only a small percentage of the database
10 considered candidate matches. Due to the nature of ballistic items and the distortions to which they are
11 subjected, and to variations in illumination resulting from aging, positioning, focus, personnel, and laboratory
12 differences, visual imaging does not provide sufficient consistency and reproducibility of feature location and
13 characteristics to facilitate such precise matching.

14 15 **DEFINITIONS**

16 Gun – device with barrel which fires a projectile, including pistols, revolvers, semiautomatics, rifles, and
17 shotguns.

18 Bore – diameter and inside surface of a gun; it may be smooth or grooved

19 Riflings – spiraled, grooved markings inside a barrel

20 Trigger - mechanism used to fire the gun by releasing the hammer which strikes a firing pin housed
21 inside the breech block

22 Firing Pin – mechanism driven into the primer area of a cartridge to initiate firing the projectile

23 Primer – firing pin strike can be center fire or rim fire

24 Cartridge - case containing the projectile or bullet; it may be reloaded for repeated use

25 Forensic Item – any item used as a weapon, or item associated with a crime which may display marks
26 related to the crime, including marks made on a human body

27 Ballistic Item – gun, bullet, shell casing, or other weapon, projectile, or element including the hands
28 which may cause or receive marks or residue associated with firing a weapon

1 Infrared camera – an imaging device whose detectors are sensitive in a spectral band between 1
2 and 14 micron; the infrared camera may have an associated spectral filter which blocks or transmits
3 segments of its band.

4 Active infrared imaging – heating or cooling the subject of the infrared image, including by sunlight,
5 hot or cold air, immersion in fluids, application of flame or ice, or other means.

6 Image sequence – one or more images of a forensic item in which the camera is focused on
7 specific features of the item

8 Reduced image sequence – an image sequence formed by selection of images which are of
9 keenest interest to a ballistics examiner

10 Features – extended marks on a forensic item visible in visual or infrared imagery caused during
11 the manufacturing process or during use. They include pits, scratches, embossing, gouges, residue, and
12 machining flaws

13 Extracted feature sequence – a processed image sequence or reduced image sequence in which
14 only features are shown

15 Image sequence focus montage – Iso referred to as a montage - combined sharp focus portions of
16 multiple images in a sequence to make one or more composite images

17 Class characteristics – features related to a particular type of weapon or ammunition and include:
18 calibre of weapon, type of ammunition, type of casing, number of lands and grooves and twist angle.

19 Tool Marks – residual markings left on an item which has been manufactured or worked using a
20 tool. In the case of a ballistic item, it can be left by the manufacturing process, by incidental use, or by use
21 as a weapon.

22 Weapon characteristics – features related to a particular weapon and may include firing pin
23 impression, breech face marks, ejector gouge, extractor mark, striations, land and groove locations

24 Residue – materials deposited on a ballistic item, including blood, oil, gun powder, dirt, grease,
25 fingerprints, body tissue, and building materials.

26 Manufacturers Mark – embossed or indented markings made during the manufacturing process, on
27 cartridges this would commonly include type and calibre of ammunition such as “30-30 WIN”

28 Orientation - position of the ballistic item relative to the axes of the camera
29

Siblings – two bullets, bullet fragments, or shell casings known to have been shot from the same weapon with the same barrel.

INTRODUCTION TO THE INVENTION

Infrared imaging of guns, fired bullets and spent casings can provide detailed definition of characteristic features free from the shadowing, glint, and focus blur associated with visible light imaging. Although IR imaging is normally associated with measurements of temperature, the imagery from an IR camera results from emissivity and geometry variations in addition to thermal changes. The tool marks which are of forensic interest on bullets and casings are associated with significant emissivity differences. In particular, deep grooves such as firing pin indentations and primer edges create highly detailed observable features in IR imagery even at ambient temperature. Use of IR imaging for ballistics identification is therefore not intended to measure temperature differences, but rather to display and analyze emissivity and geometric differences associated with indentations and embossed features of the ballistic item.

The features seen in the infrared images do not vary in position or extent as a function of illumination as do visible images. Therefore they provide stable references for alignment with other images for comparison purposes. Additional details can be obtained by active IR imaging, in which the temperature of the gun, projectile or casing is varied. This provides a sequence of images in which certain features of interest are particularly apparent at specific temperatures. This process is suggested only when it is necessary to enhance very faint features.

Summary of Benefits of IR Ballistics Identification

- Increased accuracy, speed, cost effectiveness, and ease of use.
- Provides greater definition of individual characteristics.
- No need for high energy controlled illumination
- In conjunction with visible imaging, can discriminate real features from artifacts in visual images.
- Increased automation reduces personnel requirements and personnel-induced variations..
- Allows examiner to select particular features to be matched, speeding the search and reducing false positives.
- Consistently discriminates between Land and Groove markings
- No shadows or glint created
- No variations induced by different lighting at different facilities

EVALUATION OF BALLISTIC MATCHING SYSTEMS

Current systems, such as DrugFire, compare an unknown ballistic item's image to all corresponding images in a database, producing a correlation value for each. Database images are then re-ordered based upon that correlation value, with the highest correlation ranked first. In controlled testing where the identities of all siblings are known, a measure of the accuracy and efficiency of the matching engine is the position of siblings in the re-ordering. The results shown below in the left column are taken from the DrugFire system manufactured by Mnemonics Systems [nc.. The right column shows the use of a different matching engine [FlashCorrelation® patented by the inventor] with the same visual image database as used by Mnemonics. 1157 shell casings from 229 weapons were used for the tests. The images were all taken with a conventional videomicroscope camera. MIKOS did not have the opportunity to collect its own images of the casings. Therefore, no infrared images were obtained or used for this comparison test. The purpose of this table is merely to show how ballistic matching systems are evaluated. In a smaller test, the use of infrared imagery produced significant additional improvement in position of siblings over the use of visual imagery, with nearly all siblings clustered at the very top of the ranking.

BALLISTICS MATCHING ENGINE COMPARISON TEST

1157 SHELL CASING IMAGES FROM 229 WEAPONS;
Siblings are casings fired from the same weapon

Percent of Siblings Ranked in the top P%

P%	MNEMONICS	MIKOS
2	no report	45.55 #
5	no report	57.56 #
10	49.40	68.03 #
20	63.60	79.56 #
30	72.30	85.68 #
40	79.30	90.76 #
50	84.80	94.38 #
60	88.70	97.04 #
70	93.20	99.38 #
80	96.50	100.00 #
90	98.90	100.00 #
100	100.00	100.00 #

"P" is a ranking order from 2% to 100%. Each image in the database is compared against every other, and the database is reordered by the degree of similarity with the target image. Each sibling of the target image (images of other casings fired from the same weapon) is located on the reordered list and included in the corresponding P value. Ideally all siblings would occur at the top of the rankings. The process is

1 performed for each image in the test set database in order to obtain a statistical assessment of overall
2 system performance.

3 Best indication of the relative performance of two systems would be to compare their results at $P=2\%$
4 since as P gets larger towards 100% any matching technique would produce similar results. In particular, at
5 $P=100\%$ all matching techniques achieve 100% inclusion. Mnemonics did not report rankings for P less than
6 10%. If we extrapolate the Mnemonics results to 2%, the expected value was 25%. Comparing that with
7 the 46% MIKOS value indicates that the MIKOS matching engine achieved 80% more detections at 2% than
8 did Mnemonics.

9 The intent of the ballistics matching system is to find the best matches in the database and display them
10 to a ballistics examiner who makes the final determination as to whether a match exists. The goal is to
11 minimize the work of the examiner without sacrificing accuracy. The growing size of current databases
12 requires a higher degree of automation to find links between crimes and suspects before either the statutes
13 of limitations or the suspects expire..
14

15 SUMMARY OF THE INVENTION

16 The present invention relates to a method and apparatus for comparing patterns of marks found on
17 ballistic items (including guns, bullets and shell casings) to determine whether they have common
18 characteristics which would indicate that the bullet or casing has been fired from a particular weapon. The
19 invention provides the ability to rapidly match images of an unknown ballistic item with a database of images
20 of ballistic items including guns or ammunition fired from known weapons or unknown weapons, providing
21 linkage between weapons or crimes or other events from which the guns, bullets or casings were
22 recovered.
23

24 IR IMAGING PROVIDES CONSISTENT FEATURE EXTRACTION AND CHARACTERIZATION

25 Infrared imaging of guns, fired bullets and spent casings can provide consistent and detailed definition
26 of characteristic features free from the shadowing, glint, and focus blur associated with visible light imaging.
27 Well-defined infrared imagery from casings and bullets is obtained even with the item at ambient
28 temperature. The apparent temperature differences seen are due to variations in materials, and emissivity
29 differences associated with geometry factors, and depth of markings. Therefore, the firing pin indentation,
30 its surrounding area, the primer area, and the outer ring will all appear to be at different temperatures,

although all are at room ambient. Use of the thermal imaging IR camera is therefore not intended to measure temperature differences, but rather to extract features based upon emissivity and materials differences. The resulting features can be automatically characterized, classified, and then matched against portions of the database having similarly characterized features. Since the features do not vary in position or extent due to imaging conditions, alignment of candidate matches is facilitated by

ACTIVE INFRARED IMAGERY ENHANCES THE FEATURES BUT IS OPTIONAL

Active IR imaging, in which the temperature of the gun, projectile or casing is varied, provides a collection of images at the various temperatures. Certain features of interest are particularly apparent at specific temperatures. Features associated with different materials such as the primer, or with emissivity differences such as caused by abrasion, are more well defined when viewed with an IR camera. For a given type of gun or ammunition a set of temperatures can be determined such that the sequence of images resulting from heating or cooling the gun, projectile or casing to those temperatures provides an optimized data set for matching against a database. Matching can be done using standard image processing techniques such as optical or digital correlation, or using proprietary techniques such as Flash Correlation (US 5,583,950 Method and Apparatus for N-dimensional Image Identification and Analysis).

If the ballistic item is heated and then imaged as it cools, the technique provides a sequence of images at various temperatures for each item. At certain temperatures, depending upon the composition material of the item, specific markings are enhanced. For example: serial numbers on a gun, manufacturers markings on a shell casing, striations on a bullet caused by the gun barrel, fingerprints, firing pin indentation and breech face marks on a shell casing can be characterized by size, shape, and relative location in a sequence of infrared images, as a function of imposed temperature. A feature template can be produced for each image in each sequence, by thresholding hot and cold values or other standard feature extraction techniques commonly used in image processing.

FEATURE EXTRACTION AND CHARACTERIZATION PROVIDES DATABASE PARTITIONING

Any extended area of the infrared image with apparent temperature differences from the surrounding area may be considered a feature. Using the sequence of images or extracted feature templates, significant features can be extracted and characterized prior to use of the matching engine. Characteristics of the infrared features such as area, dimensions, depth, focus setting, variation in depth and apparent

- 1 pointing to 3:00 if it is off-center; if it is also centered, then the breech marks are set parallel to the horizontal
- 2 (3:00 – 9:00).

3 For bullets, the database can be characterized according to:

- 4 • Calibre of bullet
- 5 • Material
- 6 • Length
- 7 • Number of twists
- 8 • Length of striations of maximum depth
- 9 • Number of striations vs. Length
- 10 • Relative positions of end points of striations.

11 For casing sides the database can be characterized according to:

- 12 • Calibre of bullet
- 13 • Material
- 14 • Presence of ejector mark.
- 15 • Presence of extractor mark.
- 16 • Number of striations vs. Length

Images in the casing sides and bullet databases should be formed as composites of the multiple frames taken as the bullet or casing is rotated. The composite images can be oriented so as to align striations with the horizontal plane of the image. Due to spiraling of the lands and grooves, image segments must be composed to create an image of the resulting striation pattern from the various segments imaged.

21 For images derived from thermal probes of gun barrels, the database can be characterized
22 according to:

- 23 • Calibre weapon
- 24 • Twisted bore or not.
- 25 • Number of lands and grooves
- 26 • Angle of twist.
- 27 • Relative positions of start and stop points of lands and grooves.

28 The resulting strip image should be formed into a 2-dimensional image as if the gun barrel were
29 sliced open and laid flat, and should be oriented such that the lands and grooves are horizontal in the
30 image.

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DETECTION OF ILLUMINATION-INDUCED ARTIFACTS IN VISUAL IMAGES

Since existing databases of ballistic images are all taken in the visible spectrum, utilizing those databases requires that new images also be taken in the visible domain. Due to the superior advantages of infrared imaging, it is anticipated that at some time in the future IR ballistic imaging will become standard. Meanwhile, IR images can begin to be collected for current and future use, and also to aid in exploitation of the existing databases.

By imaging in both IR and visible bands, extracting and characterizing features in each band, and comparing the results, apparent visible features which are in fact illumination-induced artifacts can be eliminated from the characterization of a ballistic item prior to matching against the database. Any true visual feature will also appear in the IR image. Eliminating artifacts will reduce the false positive error rate in visual matching.

True visible features such as striations may suffer from apparent reversal of deep and tall (e.g. land and groove) markings due to the angle of illumination. The comparable IR feature can be used as a reference to locally vary the gray-scale allocation (look-up table or LUT) in the visible image to best match that of the IR image. The result will standardize the appearance of the striations in the visible image, and improve the accuracy of the matching system.

SEPARATION OF MANUFACTURERS MARKS FROM WEAPONS MARKS

Certain markings imposed by a manufacturer, such as the calibre and manufacturer's identity on shell casings, have a characteristic depth or height which facilitates separation of those markings based upon their apparent temperature difference in infrared images. The distinction between those features and others may be further enhanced by heating or cooling the ballistic item. A template may be made from the infrared sequence which can be used to separate the manufacturers and weapons marks in the corresponding visible images. This processing step allows for separate consideration of the two sources of marks, with the realization that the two types of marks may overlap and so subtracting one type may create changes in the feature characteristics of the other which must be accommodated in the matching engine.

INFRARED IMAGES TO IDENTIFY RESIDUE IN VISUAL OR INFRARED IMAGE MATCHING

Infrared imaging can employ optical filters to assist in determining the presence and composition of gunshot residue, as well as blood, body tissue, building materials and other matter deposited on bullets

1 during their trajectory. Nitrocellulose forms carbon and the oxides of nitrate and nitrite. Other components
2 may contain barium, antimony, cooper, and lead oxides or salts. Center core primers, found in most
3 ammunition, traditionally have contained all four chemicals, but lead is now less prevalent, and rim fire
4 primers, used almost exclusively for .22 calibre, often have no barium or antimony.

5 By the use of filters, the presence of residue on the ballistic item can be determined and classified.
6 Apparent features of the ballistic item which are actually residue can be ignored for purposes of automatic
7 matching against a database. This is particularly useful in the case where residue produces an apparent
8 feature or obliterates existing features. If residue is detected, the system can provide instructions to the
9 system user that the particular ballistic item needs to be cleaned prior to further imaging.

10 Infrared imaging of the hands of suspects can also utilize spectral filters to search for gunshot
11 residue. This provides a possible immediate testing capability when a firearms investigator is not available,
12 or the scene is too contaminated to facilitate clean lifting of debris from the suspect for later analysis. By
13 combining infrared imaging of the hands and face of the suspect, the issue of chain of custody of the hands
14 samples is eliminated, since infrared images of each person's face is unique. If the infrared camera
15 annotates date and time, it minimizes the level of training and time required at the crime scene. Lift
16 samples can be taken and studied via chemical analysis using a scanning electron microscope, as is
17 traditionally done, in addition to the infrared analysis. For this application, an IR camera with automatic
18 sequencing of optical filters and video or digital output recording provides the best setup for archival
19 purposes and to support future analysis.

20 21 **APPLICATION OF INFRARED IMAGING TO ADVANCED WEAPONRY**

22 For the future, increasingly sensitive imaging and matching techniques are required: Teflon-coated
23 bullets do not pick up land and groove impressions well. Caseless bullets have been developed which
24 leave no shell casings after firing. The weapon used is an electronic .223 calibre rifle, called Lightning
25 Fire, made by Jaguar Sport. The shell exists but is constructed of propellant only. When the trigger is
26 pulled, an electric charge, not a firing pin, detonates the propellant, burning the entire casing. The
27 combination of the self-destroying shell case and Teflon bullet will provide very little evidence for evaluation.
28 Active infrared imaging of such bullets may provide sufficient information for identification and matching.

1 IMAGE MONTAGE CREATION

2 A composite image or images can be created by combining the best focused local image of each true
3 feature of a ballistic item to create an image of the entire item in which each feature is in its relative position
4 and in focus. The montaged images can be displayed to the ballistics examiner and/or first used in
5 automated correlation processing to determine candidate matching items. This step can be performed for
6 either visible or infrared image sequences and matching procedures.

8 DESCRIPTION OF THE APPARATUS

9 The apparatus consists of the following components:

- 10 1. Infrared imaging microscope having radiometric calibration for each image frame output, such that
11 a given gray level corresponds to a particular apparent temperature. Variable focus optics allow for detailed
12 in-focus imaging over the full range of depth and height of the ballistic item features.
- 13 2. Shroud to avoid ambient light striking the ballistic item to cause reflections or heating.
- 14 3. Holders for shell casings such that the back end is viewed normal to the camera axis.
- 15 4. Holders for shell casings such that the side is normal to the camera axis and the casing can be
16 rotated for a full 360° image.
- 17 5. Holder for essentially undeformed bullets such that the bullet can be rotated and all of the surface
18 can be imaged normal to the camera axis.
- 19 6. Holders for deformed bullets such that multiple images can be taken which will encompass the
20 entire surface area. Assume the bullet may have no obvious axis or center; the need is to completely image
21 the surface. Multiple positionings may be needed.
- 22 7. Holder for gun which facilitates operation of an infrared probe which has a helical scanning rotating
23 head and forms an infrared image of the inside of the barrel of a gun as it cools.
- 24 8. (Optional) Heater subsystem which can be on-line: radiant heat lamps, hot air, direct contact
25 electric heat; or off-line: boiling in water or other liquid, heating in a controlled oven.
- 26 9. (Optional) Spectral filters, which can be used to obtain additional image information such as the
27 composition of the ballistic item, including material of the casing, material of the bullet, type of primer.
28 Alternately, the system user can determine these characteristics.
- 29 10. Feature Extraction Engine, which can be image processing software, firmware or hardware to
30 locate local areas of interest in the image.

Figure 12 illustrates minutiae obtained from Figure 11. In this example, minutiae were defined as pixels whose nearest neighbors had grey values differing by more than 8 gray levels. Matching can be performed based upon the minutiae, analogous to matching of fingerprint minutiae.

Figure 13 presents a block diagram of the apparatus configured with the following subsystems:

- (1) image capture and display, including the ballistic examiner's display, feature highlighter, and interactive devices.
- (2) feature extraction and characterization.
- (3) database matching and updating.

Figure 14 presents a hypothetical graph of the apparent size of a feature as a function of gray scale values (or temperatures) included in the feature, using different spectral bands. Such graphs can be used to automatically determine the material of the item including principal and trace components, the type of weapon, and the manufacturer.

DETAILED DESCRIPTION OF THE FIRST EMBODIMENT –

USING INFRARED IMAGES TO REFINE VISIBLE IMAGE DETAILS FOR BALLISTICS IDENTIFICATION IMAGE AND INFORMATION CAPTURE

A ballistic item 10 is placed in a holder 12 and surrounded by a shroud 14 covering it and an infrared camera 16 such that external lighting and heating sources are blocked. The camera focus mechanism 18 is varied over a range such that all details of the infrared image of the ballistic item are clearly captured in a sequence of infrared images 20.

Optionally, one or more spectral filters 30 can be installed and additional sequences of infrared images obtained. Optionally, a heater 32 can be used to raise the temperature of the ballistic item and additional sequences of infrared images obtained for the item at the elevated temperature and as it cools.

A controlled light source 110 is then turned on to illuminate the ballistic item and a video camera 116 is used to produce a sequence of visible images 120 by varying the focus mechanism 18.

Each image is annotated with date and time, workstation #, item temperature, focus setting, and item reference number. The focus and image capture processes can be automated such that a succession of minute variations in focus is performed and an image taken at each step, or the focus and image capture can be manually controlled using an examiner's workstation consisting of a display screen 22 and input controls 24 including any combination of keyboard, mouse, voice, or similar device. The workstation also

Text information is entered which identifies the ballistics item and related information such as case #, weapon type, ammunition type, location where found, etc. That information can be read from an evidence tag using a bar code reader 28 or input through the controls of the examiners workstation such as by keyboard. The text information can be displayed on the screen 22 along with the corresponding annotated image.

Both text information and image sequences are stored in an infrared image sequence database 26 and a visible image sequence database 126.

FEATURE EXTRACTION AND CHARACTERIZATION

The sequences of visible images are processed to extract and characterize apparent features at 142 using any of various standard automated image processing techniques or by manual highlighting by the examiner. Characterization a minimum includes the relative positions of features, their shape, their area and perimeter length, and variation in gray scale distribution within the feature. Similar processing is performed at 42 on the infrared sequences using the same or similar processing.

For each visible feature, one image is selected from the sequence in which that feature is in sharp focus. The feature area of that image is extracted and used to create a montaged visible image 138 in which each feature is shown and each is in sharp focus. The same is done for the infrared sequence to create a montaged infrared image 38. Each montaged image is associated with the characterizations of the associated features at 42 and 142.

IMAGE COMPARISON AND CORRECTIONS TO VISIBLE IMAGES

The characteristics of the montaged visible image 138 and montaged infrared image 38 are compared at 136. Any feature of the visible montaged image 138 which does not have a corresponding infrared montaged feature in image 38 is removed from image 138. Correspondence requires at a minimum overlapping locations and similar shapes. Those removed visible features are considered to be illumination-induced artifacts. Any visible feature which has a corresponding infrared feature, but which differs in gray scale distribution from the IR feature is subjected to variation in its gray scale allocation or LUT 134 to find the best correlation with the corresponding infrared feature. Those visible features are considered to have illumination-induced gray scale reversals. Any infrared feature which does not have a corresponding visible feature is considered to represent a possible true feature hidden in the visible image

1 due to shadow. At the option of the examiner, such features can be (1) copied from the infrared montaged
2 image to the visible montaged image, (2) annotated such as in color on the visible montaged image, (3)
3 tested by the use of spectral filters and/or heating to determine if it results from residue, in which case the
4 item should be cleaned and re-imaged.

5 The resulting montaged infrared and visible images, along with their characteristics and textual
6 information are entered into a database of infrared characterizations 50 and enhanced visible
7 characterizations 150 of unknown ballistic items. The enhanced visible characterization can then be used
8 with current ballistic identification methods and apparatus, producing more accurate results due to the
9 elimination of illumination-induced artifacts, and the detection of hidden features due to shadow.

11 DETAILED DESCRIPTION OF THE SECOND EMBODIMENT –

12 BALLISTICS IDENTIFICATION THROUGH MATCHING INFRARED CHARACTERISTICS

13 When infrared imaging alone is used for ballistics identification, without use of corresponding visible
14 images, then components 100, 118, 120, 126, 138, 142, 134, 150 and references to visible images,
15 sequences, features, and montages can be eliminated from the apparatus description.

17 IMAGE AND INFORMATION CAPTURE

18 A ballistic item 10 is placed in a holder 12 and surrounded by a shroud 14 covering it and an
19 infrared camera 16 such that external lighting and heating sources are blocked. The camera focus
20 mechanism 18 is varied over a range such that all details of the infrared image of the ballistic item are
21 clearly captured in a sequence of infrared images 20.

22 Optionally, one or more spectral filters 30 can be installed and additional sequences of infrared
23 images obtained. Optionally, a heater 32 can be used to raise the temperature of the ballistic item and
24 additional sequences of infrared images obtained for the item at the elevated temperature and as it cools.

25 Each image is annotated with date and time, workstation #, item temperature, focus setting, and
26 item reference number. The focus and image capture processes can be automated such that a succession
27 of minute variations in focus is performed and an image taken at each step, or the focus and image capture
28 can be manually controlled using an examiners workstation consisting of a display screen 22 and input
29 controls 24 including any combination of keyboard, mouse, voice, or similar device. The workstation also
30 contains highlighting device 90 for manually specifying areas of images or textual information of particular

interest to the examiner. The highlighter can be any combination of touch screen, lightpen, graphics tablet, or similar device. The display 22 has the ability to mosaic several images on a single screen.

Text information is entered which identifies the ballistics item and related information such as case #, weapon type, ammunition type, location where found, etc. That information can be read from an evidence tag using a bar code reader 28 or input through the controls of the examiners workstation such as by keyboard. The text information can be displayed on the screen 22 along with the corresponding annotated image.

Both text information and image sequences are stored in an image sequence database 26.

FEATURE EXTRACTION AND CHARACTERIZATION

The sequences of infrared images are processed to extract and characterize apparent features at 42 using any of various standard automated image processing techniques or by manual highlighting by the examiner. Characterization at a minimum includes the relative positions of features, their shape, their area and perimeter length, and variation in gray scale distribution within the feature

For each apparent infrared feature, one image is selected from the sequence in which that feature is in sharp focus. The feature area of that image is extracted and used to create a montaged infrared image 38 in which each feature is shown and each is in sharp focus. If there is the chance that debris may remain on the ballistic item, then apparent features may in fact be debris. This event can be tested for by comparing corresponding focus images using different spectral filters 30. Apparent features which persist through a range of filters are considered actual features. Each montaged image is then associated with the characterizations of the associated features at 42.

IDENTIFICATION USING MATCHING

When the unknown ballistic item characterized in 50 has been identified or linked with other known items, by a ballistics examiner or an automated system, its file is move to relational database 60 which then includes (1) textual information related to the case, its disposition, location of the item, names and dates, weapon information and links to other forensic and law enforcement databases; (2) images which may include the montaged feature images alone or also the image sequences, and may also include highlights created by a ballistics examiner and corresponding notes, which should be displayed in color for emphasis;

and (3) feature characteristics including a summary of the number and types of features seen, and details on each feature including type, shape, size, location, and variation in gray scale and edge effects.

Database 60 will contain characterization of known or linked ballistic items. When an unknown item 10 is presented for identification, it is processed as detailed above to produce its characterization at 50. The resulting characteristics are used to select initial candidates from the database 60 based upon text, image, and feature characteristics which are relatively immune to error or variation. For example, the calibre of ammunition. In matching shell casings, if the unknown firing pin indentation is centered, only database entries with centered firing pins are considered as potential candidates. The presence or breech face markings, ejector or extractor marks may also be considered relatively immune to error or variation.

The initial candidate matches are then further processed using the text matching engine 70 which might provide for example the date of manufacture of the weapon, meaning that all ballistic items collected prior to that date need not be considered as matches. Other information is compared and scored as to similarity, such as information about the type of crime associated with the ballistics item, the locale where the item was collected, the presence of other similar items at the same collection, etc. The similarity score will generally not exclude candidates from further consideration, but may influence their rank ordering in presentation to a ballistics examiner for consideration below.

Remaining candidate matches are then further processed using the feature matching engine 72 which first compares summary characteristics such as the number and type of features, and then compares the details of each feature of the unknown and candidate items. Various metrics or scoring techniques can be defined to calculate a goodness of match based upon the feature characteristics. Fingerprint matching and face matching technique are especially suitable, with Prokoski et. al U.S. Patent 5/63094, as an example. Candidates which do not correlate sufficiently with the unknown item are not longer considered.

Remaining candidate matches are then further processed by correlating the montaged images using an image processing technique such as Prokoski U.S. Patent 5583950 to produce an image correlation value. Other image processing comparison techniques may be used.

The remaining candidates are then rank ordered based upon their text similarity score, their feature characteristics goodness of match, and their image correlation value. Various algorithms for performing the rank ordering can be used. An effective one is to assign a rank ordering based on each of the three measures, and then perform a composite rank ordering based upon the ordinal sum of the component rank orderings.

1 d. display the similar pairs of images to a ballistics examiner who reviews the display and rules that
2 the unknown ballistic item is a match to an item in the database if the similar pair(s) of images are
3 sufficiently alike.

4
5 6. Method of Claim 5. In which step f is performed automatically by further image processing

6
7 7. Method of Claims 5 or 6 including also the step:

8 e. compare the weapon-specific and incident-specific tagging information of the similar image pairs

9 a. Display the similarities and dissimilarities in the tagging information along with the images for

10 further consideration by a ballistics examiner who reviews the display and rules that the

11 unknown ballistic item is a match to an item in the database if the tagging information as well as

12 the similar pair(s) of images are sufficiently alike.

13
14 8. Method of Claim 7 in which step i. is performed automatically by further image processing.

15
16 9. Method for identification of a ballistic item including the steps:

17 a. characterize the unknown ballistic item by producing a tagged extracted feature sequence

18 b. compare the extracted feature sequence with those contained in a database

19 c. determine those sequences in which one or more extracted features are similar to the unknown

20 extracted feature sequence

21 d. display the similar pairs of extracted features to a ballistics examiner who reviews the display

22 and rules that the unknown ballistic item is a match to an item in the database if the similar pair(s) of

23 extracted features are sufficiently alike.

24
25 10. Method of Claim 9. In which step d is performed automatically by further image processing

26
27 11. Method of Claims 9 or 10 including also the steps:

28 e. compare the weapon-specific and incident-specific tagging information of the similar extracted

29 feature pairs

1 f. Display the similarities and dissimilarities in the tagging information along with the extracted
2 features for further consideration by a ballistics examiner who reviews the display and rules that the
3 unknown ballistic item is a match to an item in the database if the tagging information as well as the similar
4 pair(s) of extracted features are sufficiently alike.

5
6 12. Method of Claim 11 in which step f. Is performed automatically by further image processing.

7
8 13. Method of Claim 1 including also the steps:

9 e. heating or cooling the ballistic item to vary its temperature

10 f. producing an image sequence in which both focus and temperature are varied

11 g. tagging each image with the corresponding temperature.

12
13 14. Method to identify illumination-induced artifacts in visible light photography of ballistic items including
14 the steps:

15 a. Produce visible and IR image sequences of the same ballistic item

16 b. extract features from each image in each sequence

17 c. tag as a candidate illumination-induced artifact each feature in a visible image which does not
18 have a corresponding IR feature

19 d. tag dark visible artifacts as possible shadows and light artifacts as possible glint

20
21 15. Method of claim 14 in which spectral filters are used to tag certain artifacts as possible debris including
22 oil, gunpowder, fingerprints.

23
24 16. Method for distinguishing lands and grooves in visible light photography of ballistic items including the
25 steps:

26 a. produce visible and IR image sequence of the same ballistic item

27 b. extract features from each image in each sequence

28 c. readjust the look-up table of gray scale allocation for the visible image such that the resulting
29 image most closely matches that of the IR image

d. Display the resulting visible image which will have more consistent appearance of lands vs. grooves.

17. Method to differentiate manufacturing marks and weapons-related tool marks on shell casings including the steps:

- a. adjust the focus on the IR camera such that the manufacturing marks are in focus
- b. adjust the temperature of the ballistic item such that the manufacturing marks are most distinct from the surrounding area
- b. threshold the resulting image to create a template of the manufacturing marks to be used for matching or for eliminating the marks from that image prior to further matching

18. Method to detect residue on a ballistic item, including the steps:

- a. apply a sequence of spectral filters to the IR camera
- b. for each filter, vary the focus to produce an image sequence
- c. extract features from each image in the sequence
- d. compare the feature sets in images which have the same focus setting but different spectral filters
- e. display those features which are filter-sensitive as possible residue
- f. Annotate features with likely type of residue based upon the filter sensitivity.

19. Apparatus for characterizing a ballistic item including:

- a. IR camera with lenses and focus control
- b. Mechanism for varying the focus control to produce a sequence of images
- c. Image digitizer and storage
- c. Mechanism for tagging images with ancillary information
- d. Feature extractor
- e. Processor for characterizing the features
- f. Processor for creating a montage
- g. Display
- h. Mechanism for positioning the item within the camera field of view

1 20. The apparatus of claim 19 including also the elements:

- 2 i. device for heating the ballistic item
- 3 j. device for measuring the temperature of the ballistic device
- 4 k. device for applying optical filters before the camera lens
- 5 l. mechanism for tagging the resulting images with temperature and filter data

7 21. Apparatus for identifying a ballistic item including the elements of 20 plus:

- 8 m. Database of characterized ballistic items
- 9 n. Database matching engine
- 10 o. Output or display mechanism

12 22. Method for identifying a ballistic item including the steps

- 13 a. for each montaged image in the unknown item database and the known item database produce
- 14 a relative location map as follows:
- 15 b. compute the centroid location for each feature, including all striations, gouges, breech face
- 16 marks, and firing pin indents, where each striation is considered a separate feature.
- 17 c. Compute the distances between each pair of centroids
- 18 d. Tag the distances with the type of feature represented at each end
- 19 e. Match the list of tagged distances with corresponding lists for the known item database.

21 23. Method for separating manufacturers marks from weapons marks in ballistic images, including the
22 steps:

- 23 a. heating the ballistic item to temperature which enhances the manufacturers marks
- 24 b. producing an infrared image of the ballistic item
- 25 c. producing a template of the areas containing the enhanced manufacturers marks
- 26 d. extracting the template areas to form an image containing the manufacturers marks
- 27 e. the remaining image containng no manufacturers marks but containing weapons marks which did
- 28 not overlay manufacturers marks.

- 1 24. Method for estimating the volume of grooves, indentations and striations in ballistic items including the
- 2 steps:
- 3 a. heat the ballistic item to an elevated temperature
- 4 b. measure the mean temperature of the item using the radiometric infrared camera
- 5 c. capture a sequence of images as the item cools
- 6 d. capture for each image the mean temperature using the radiometric camera
- 7 e. estimate the volume of each depressed feature by determining its heat loss rate relative to the
- 8 mean temperature of the item, considering also the materials composition of the item.

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ABSTRACT

Systematic use of infrared image analysis in conjunction with currently used visible image analysis techniques provides significant improvements in automated analysis of tool marks. In particular, the method and apparatus of this patent identify illumination-induced artifacts such as glint and shadow, detect features such as additional striations hidden by shadows, and correct for apparent reversal of lands and grooves due to the angle of illumination used to obtain the visible images. By using the infrared images to detect and eliminate artifacts and make local corrections to features in the visible images, the resulting matching of visible tool mark images against a database of similar images produces more accurate matching with a greater number of located matches. Since current databases of tool marks, including ballistic signatures, contain visible images only, the use of infrared analysis may be initially limited to pre-processing new images compared with and added to the databases.

As infrared camera prices are reduced, it is predicted that the IR analysis methods of this patent will become the standard matching technique, due to their significant advantages. Infrared analysis of tool marks provides classification, alignment, characterization, comparison, matching and identification of such marks with better specificity and repeatability than analysis in the visible spectrum. In the case of ballistics item matching, the proposed method and apparatus can automatically extract and characterize the marks associated with a particular manufacturing process or caused by a particular weapon including: striations, firing pin indentation, breech, extractor and ejector marks, resulting in more accurate automated matching against databases of bullets, casings, and weapons.

The method can be enhanced by active infrared imaging which includes heating or cooling the item under examination to enhance markings which have different depths of surface features or which are caused by differing emissivities due to surface abrasion or due to differing materials. The method can also be enhanced by imaging using a range of spectral filters. This provides compositional analysis of the material of the ballistic item and the nature of any identified debris on the item.

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- 19
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- 21
- 22
- 23

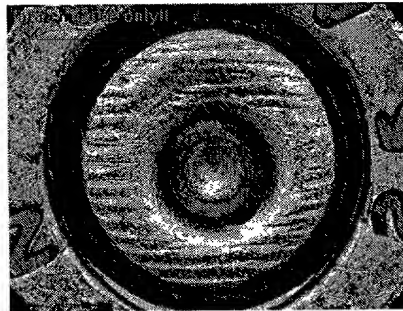


FIGURE 1a

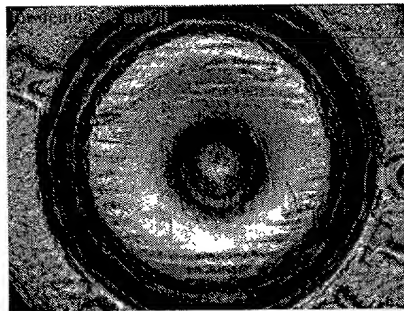


Figure 1b

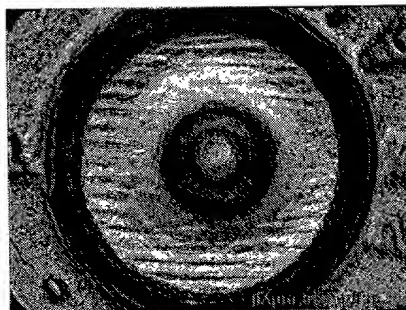


Figure 1c

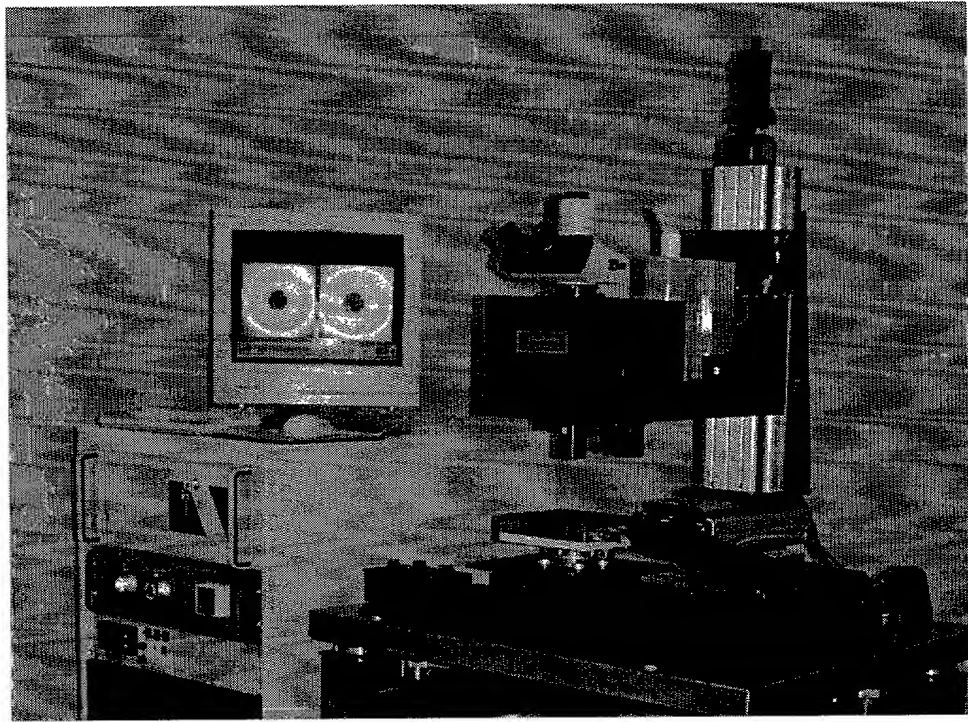


FIGURE 2

650 7 06 06



FIGURE 3

ENCLOSURE

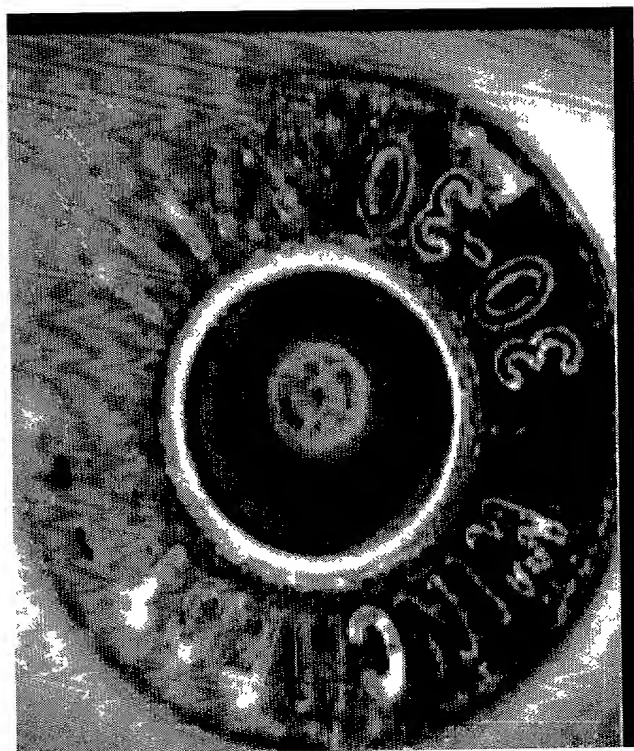


FIGURE 4

[REDACTED]

SECRET



FIGURE 5

A high-contrast, black and white photograph of a textured surface, possibly a book cover or endpaper. The image shows a curved edge on the right side, with a vertical strip of lighter material running down the center. The overall texture is grainy and mottled, with a dark, irregular shape in the upper left corner. The image is oriented vertically.

[The following text is extremely faint and largely illegible due to extreme vertical compression. It appears to contain several paragraphs of handwritten notes.]



[The following text is extremely faint and largely illegible due to extreme vertical compression. It appears to contain several paragraphs of handwritten notes.]

SECRET

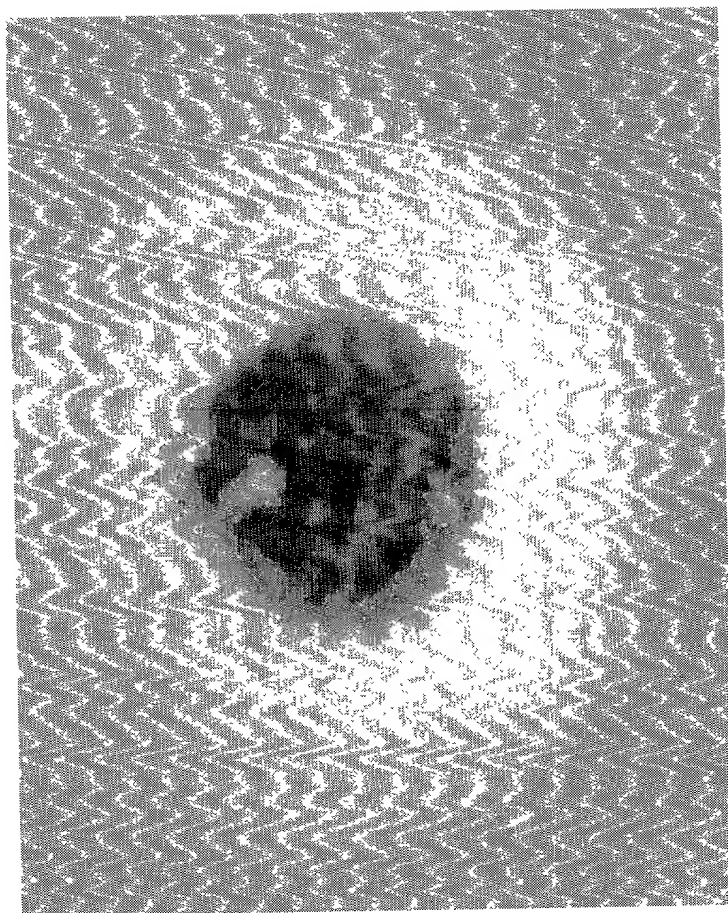


FIGURE 8

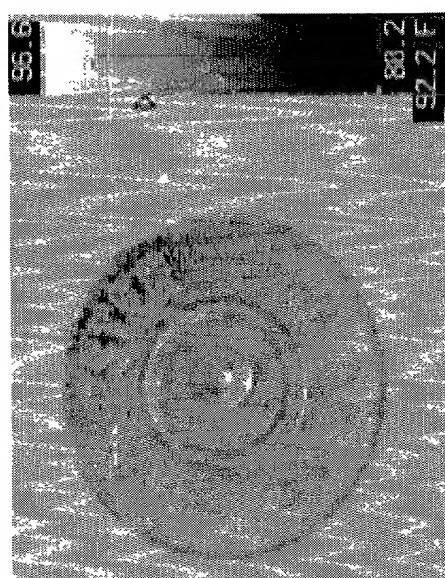
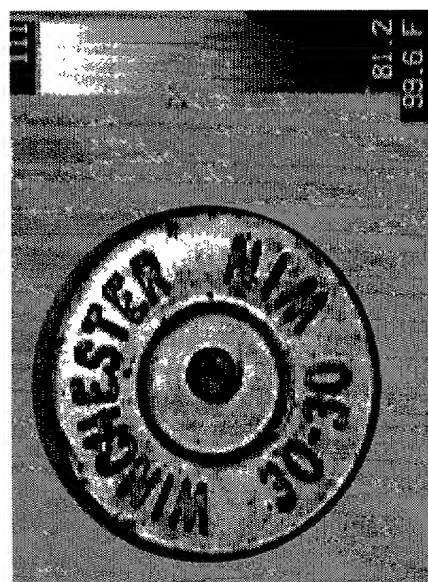


FIGURE 10

[illegible]11
12

姓名	性别	年龄	籍贯	职业	文化程度	健康状况	婚姻状况	子女情况	其他
王德胜	男	45	山东	工人	高中	良好	已婚	2子1女	
李秀英	女	42	河北	教师	大学	良好	已婚	1子1女	
张国强	男	38	河南	农民	初中	良好	已婚	2子1女	
刘小红	女	35	江苏	护士	中专	良好	已婚	1子1女	
陈为民	男	50	浙江	干部	大学	良好	已婚	2子1女	
赵大伟	男	40	湖北	工人	高中	良好	已婚	1子1女	
孙丽娟	女	30	广东	教师	大学	良好	已婚	1子1女	
周建明	男	48	四川	农民	初中	良好	已婚	2子1女	
吴小芳	女	33	湖南	护士	中专	良好	已婚	1子1女	
郑为民	男	55	安徽	干部	大学	良好	已婚	2子1女	
冯大刚	男	43	江西	工人	高中	良好	已婚	1子1女	
李秀珍	女	37	福建	教师	大学	良好	已婚	1子1女	
张国强	男	39	广西	农民	初中	良好	已婚	2子1女	
刘小红	女	34	云南	护士	中专	良好	已婚	1子1女	
陈为民	男	51	贵州	干部	大学	良好	已婚	2子1女	
赵大伟	男	41	海南	工人	高中	良好	已婚	1子1女	
孙丽娟	女	31	宁夏	教师	大学	良好	已婚	1子1女	
周建明	男	49	青海	农民	初中	良好	已婚	2子1女	
吴小芳	女	32	甘肃	护士	中专	良好	已婚	1子1女	
郑为民	男	56	陕西	干部	大学	良好	已婚	2子1女	
冯大刚	男	44	山西	工人	高中	良好	已婚	1子1女	
李秀珍	女	38	内蒙古	教师	大学	良好	已婚	1子1女	
张国强	男	40	吉林	农民	初中	良好	已婚	2子1女	
刘小红	女	35	黑龙江	护士	中专	良好	已婚	1子1女	
陈为民	男	52	辽宁	干部	大学	良好	已婚	2子1女	
赵大伟	男	42	吉林	工人	高中	良好	已婚	1子1女	
孙丽娟	女	32	黑龙江	教师	大学	良好	已婚	1子1女	
周建明	男	50	辽宁	农民	初中	良好	已婚	2子1女	
吴小芳	女	33	吉林	护士	中专	良好	已婚	1子1女	
郑为民	男	57	黑龙江	干部	大学	良好	已婚	2子1女	
冯大刚	男	45	辽宁	工人	高中	良好	已婚	1子1女	
李秀珍	女	39	吉林	教师	大学	良好	已婚	1子1女	
张国强	男	41	黑龙江	农民	初中	良好	已婚	2子1女	
刘小红	女	36	辽宁	护士	中专	良好	已婚	1子1女	
陈为民	男	53	吉林	干部	大学	良好	已婚	2子1女	
赵大伟	男	43	黑龙江	工人	高中	良好	已婚	1子1女	
孙丽娟	女	33	辽宁	教师	大学	良好	已婚	1子1女	
周建明	男	51	吉林	农民	初中	良好	已婚	2子1女	
吴小芳	女	34	黑龙江	护士	中专	良好	已婚	1子1女	
郑为民	男	58	辽宁	干部	大学	良好	已婚	2子1女	
冯大刚	男	46	吉林	工人	高中	良好	已婚	1子1女	
李秀珍	女	40	黑龙江	教师	大学	良好	已婚	1子1女	
张国强	男	42	辽宁	农民	初中	良好	已婚	2子1女	
刘小红	女	37	吉林	护士	中专	良好	已婚	1子1女	
陈为民	男	54	黑龙江	干部	大学	良好	已婚	2子1女	
赵大伟	男	44	辽宁	工人	高中	良好	已婚	1子1女	
孙丽娟	女	34	吉林	教师	大学	良好	已婚	1子1女	
周建明	男	52	黑龙江	农民	初中	良好	已婚	2子1女	
吴小芳	女	35	辽宁	护士	中专	良好	已婚	1子1女	
郑为民	男	59	吉林	干部	大学	良好			



姓名	性别	年龄	籍贯	职业	文化程度	健康状况	婚姻状况	子女情况	其他
王德胜	男	45	山东	工人	高中	良好	已婚	2子1女	
李秀英	女	42	河北	教师	大学	良好	已婚	1子1女	
张国强	男	38	河南	农民	初中	良好	已婚	2子1女	
刘小红	女	35	江苏	护士	中专	良好	已婚	1子1女	
陈为民	男	50	浙江	干部	大学	良好	已婚	2子1女	
赵大伟	男	30	广东	学生	高中	良好	未婚	无	
孙丽娟	女	28	四川	医生	大学	良好	未婚	无	
周建明	男	40	湖北	工人	初中	良好	已婚	2子1女	
吴小芳	女	33	湖南	教师	高中	良好	已婚	1子1女	
郑为民	男	48	安徽	农民	小学	良好	已婚	2子1女	
冯大刚	男	36	江西	工人	初中	良好	已婚	2子1女	
马秀珍	女	41	山西	教师	大学	良好	已婚	1子1女	
徐国强	男	39	陕西	干部	高中	良好	已婚	2子1女	
刘小红	女	34	甘肃	护士	中专	良好	已婚	1子1女	
陈为民	男	49	宁夏	工人	初中	良好	已婚	2子1女	
赵大伟	男	31	青海	学生	高中	良好	未婚	无	
孙丽娟	女	29	新疆	医生	大学	良好	未婚	无	
周建明	男	43	内蒙古	工人	初中	良好	已婚	2子1女	
吴小芳	女	37	辽宁	教师	高中	良好	已婚	1子1女	
郑为民	男	46	吉林	农民	小学	良好	已婚	2子1女	
冯大刚	男	35	黑龙江	工人	初中	良好	已婚	2子1女	
马秀珍	女	44	山东	教师	大学	良好	已婚	1子1女	
徐国强	男	42	河北	干部	高中	良好	已婚	2子1女	
刘小红	女	36	河南	护士	中专	良好	已婚	1子1女	
陈为民	男	51	江苏	工人	初中	良好	已婚	2子1女	
赵大伟	男	32	浙江	学生	高中	良好	未婚	无	
孙丽娟	女	30	广东	医生	大学	良好	未婚	无	
周建明	男	47	四川	工人	初中	良好	已婚	2子1女	
吴小芳	女	38	湖北	教师	高中	良好	已婚	1子1女	
郑为民	男	49	湖南	农民	小学	良好	已婚	2子1女	
冯大刚	男	37	安徽	工人	初中	良好	已婚	2子1女	
马秀珍	女	45	江西	教师	大学	良好	已婚	1子1女	
徐国强	男	43	山西	干部	高中	良好	已婚	2子1女	
刘小红	女	37	陕西	护士	中专	良好	已婚	1子1女	
陈为民	男	52	甘肃	工人	初中	良好	已婚	2子1女	
赵大伟	男	33	宁夏	学生	高中	良好	未婚	无	
孙丽娟	女	31	青海	医生	大学	良好	未婚	无	
周建明	男	48	新疆	工人	初中	良好	已婚	2子1女	
吴小芳	女	39	内蒙古	教师	高中	良好	已婚	1子1女	
郑为民	男	50	辽宁	农民	小学	良好	已婚	2子1女	
冯大刚	男	38	吉林	工人	初中	良好	已婚	2子1女	
马秀珍	女	46	黑龙江	教师	大学	良好	已婚	1子1女	
徐国强	男	44	山东	干部	高中	良好	已婚	2子1女	
刘小红	女	38	河北	护士	中专	良好	已婚	1子1女	
陈为民	男	53	河南	工人	初中	良好	已婚	2子1女	
赵大伟	男	34	浙江	学生	高中	良好	未婚	无	
孙丽娟	女	32	广东	医生	大学	良好	未婚	无	
周建明	男	49	四川	工人	初中	良好	已婚	2子1女	
吴小芳	女	40	湖北	教师	高中	良好	已婚	1子1女	
郑为民	男	51	湖南	农民	小学	良好	已婚	2子1女	

FIGURE 13

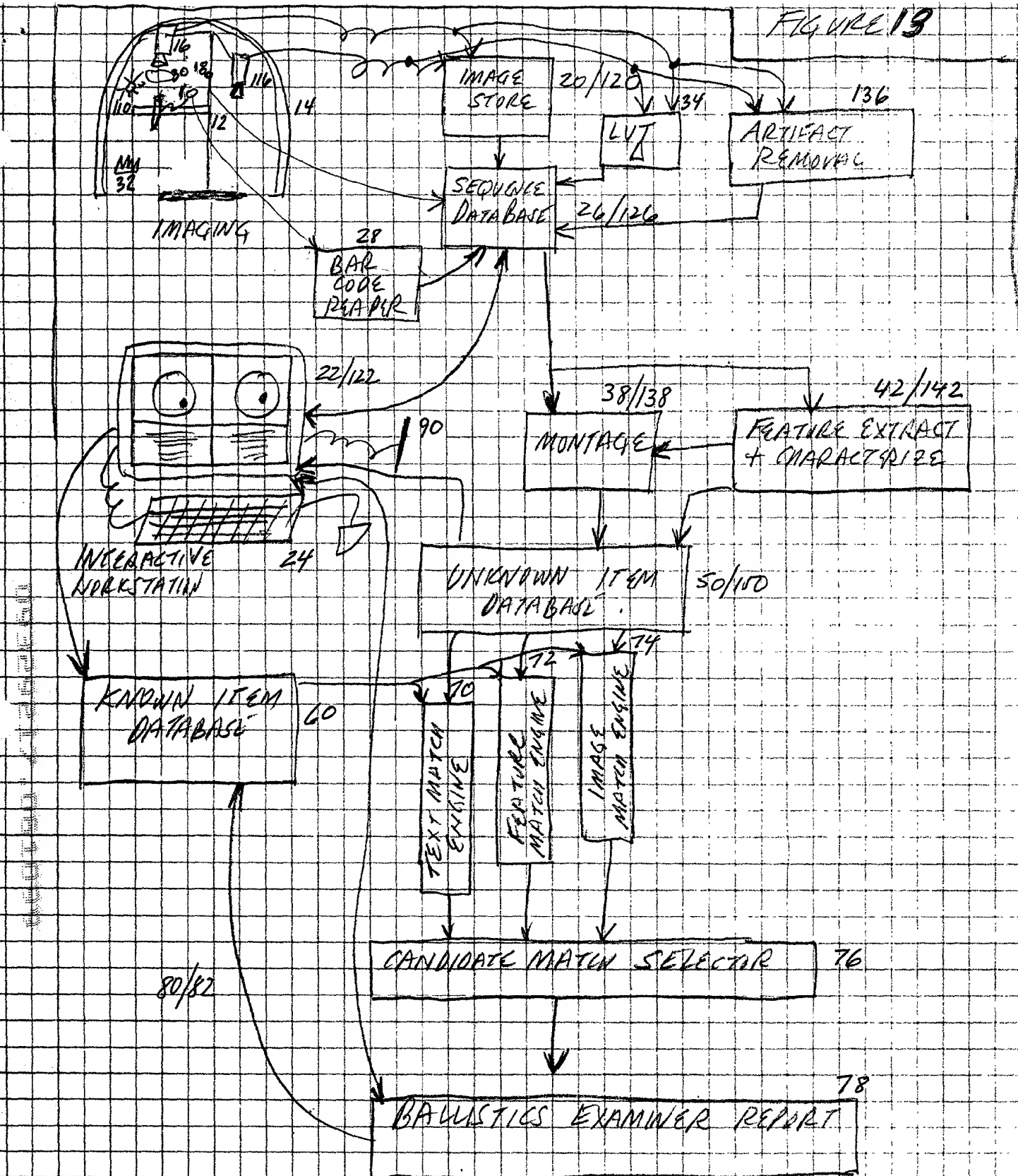
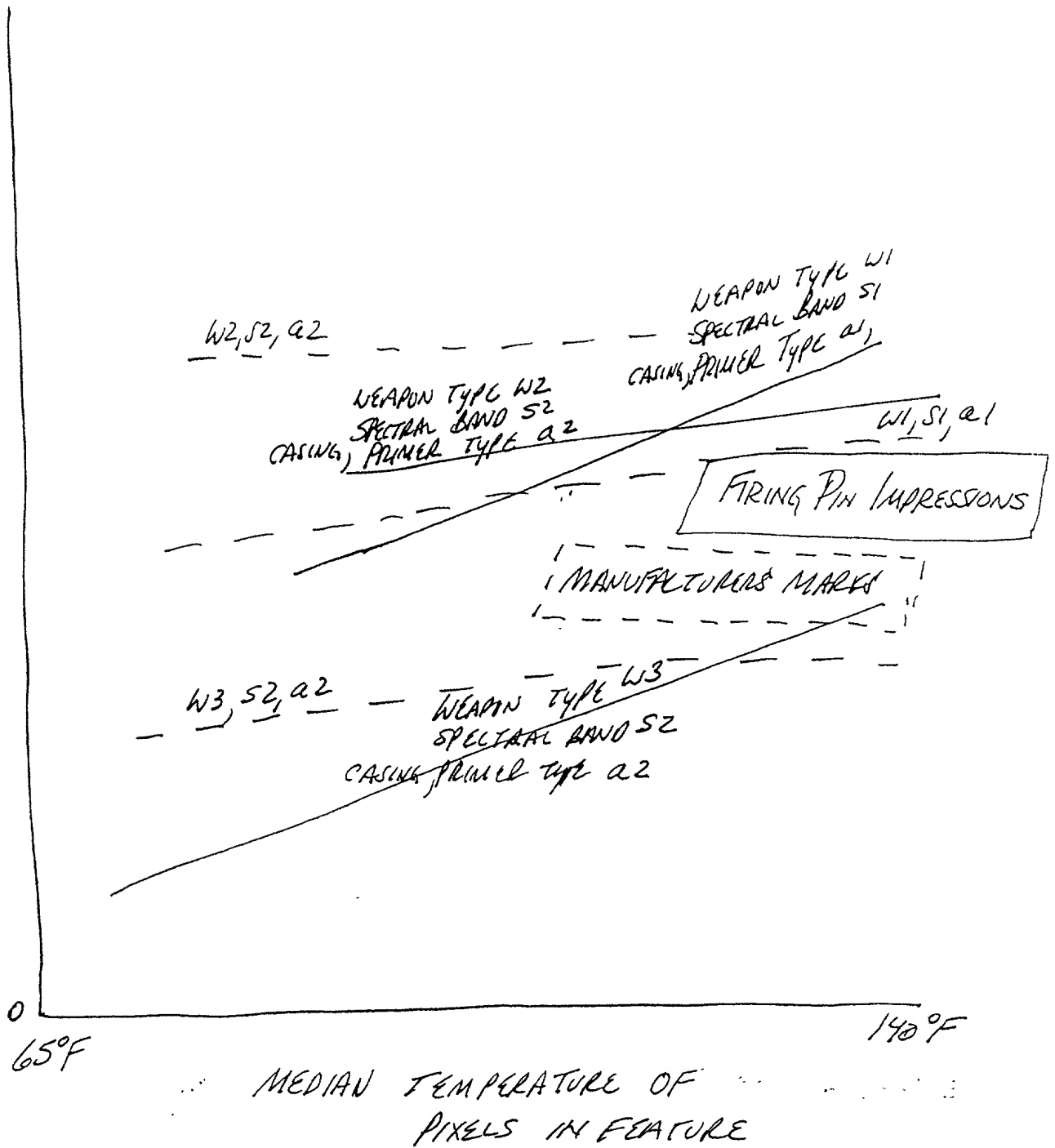


FIGURE 14

NUMBER OF PIXELS IN FEATURE



**DECLARATION FOR
UTILITY PATENT APPLICATION**

As the below-named inventor, I hereby declare that:

My residence address and citizenship are as stated below next to my name.

I BELIEVE I THE ORIGINAL, FIRST AND SOLE INVENTOR OF THE SUBJECT MATTER WHICH IS CLAIMED AND FOR WHICH A PATENT IS SOUGHT ON THE INVENTION ENTITLED:

METHOD AND APPARATUS FOR ALIGNMENT, COMPARISON & IDENTIFICATION OF
CHARACTERISTIC TOOL MARKS, INCLUDING BALLISTIC SIGNATURES

the specification of which

☒ is attached hereto;
☐ was filed on ____ as Application Serial No. _
and was amended on _____;

I HAVE REVIEWED AND UNDERSTAND THE CONTENTS OF THE ABOVE-IDENTIFIED SPECIFICATION, INCLUDING THE CLAIMS, AS AMENDED BY ANY AMENDMENT REFERRED TO ABOVE;

I ACKNOWLEDGE THE DUTY TO DISCLOSE TO THE OFFICE ALL INFORMATION KNOWN TO BE MATERIAL TO PATENTABILITY AS DEFINED IN TITLE 37, CODE OF FEDERAL REGULATIONS, Sec. 1.56 (as amended effective March 16, 1992);

I do not know and do not believe the said invention was even known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to said application; that said invention was not in public use or on sale in the United States of America more than one year prior to said application; that said invention has not been patented or made the subject of an inventor's certificate issued before the date of said application in any country foreign to the United States of America on any application filed by me or my legal representatives or assigns more than twelve months prior to said application;

I hereby claim foreign priority benefits under Title 35, United States Code Sec. 119 and/or Sec. 365 of any foreign applications(s) for patent or inventor's certificate as indicated below and have also identified below any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application(s) on which priority is claimed:

Address all correspondence to:

Dr. Francine Prokoski, POB 7025, Fairfax Station, Virginia 22039 USA

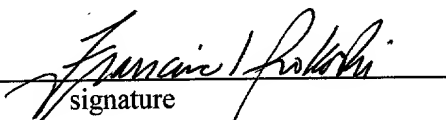
Address all telephone calls to:

703 493 9300, fax 703 690 7435, internet mikos@gte.net

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

FRANCINE J. PROKOSKI

full name of sole inventor


signature


date

POB 7025 Fairfax Station, VA 22039, USA

residence

USA

citizenship

660150-1 12666600